Exhibit A

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
SAN FRANCISCO DIVISION

IN RE: TFT-LCD (FLAT PANEL) ANTITRUST LITIGATION,

Master File No.: 07-MD-1827 SI

THIS DOCUMENT RELATES TO:

MDL NO. 1827

AT&T MOBILITY LLC, et al., v. AU OPTRONICS CORPORATION, et al. No. 09-cv-4997-SI

COSTCO WHOLESALE CORPORATION v. AU OPTRONICS CORPORATION, et al. No. 3:11-cv-00058-SI

DELL INC. and DELL PRODUCTS L.P., v. SHARP CORPORATION, et al. No. 3:10-cv-01064 SI

EASTMAN KODAK COMPANY v. EPSON IMAGING DEVICES CORPORATION, et al., No. 3:10-CV-05452-SI

ELECTROGRAPH SYSTEMS, INC., et al., v. EPSON IMAGING DEVICE CORPORATION, et al., No. 3:10-cv-00117 SI

MOTOROLA, INC., v. AU OPTRONICS CORPORATION, et al., No. 09-cv-5840-SI

TARGET CORPORATION, et al v. AU OPTRONICS CORPORATION., et al., No. 3:10-cv-4945 SI

EXPERT REPORT OF JAMES A. LEVINSOHN, PH.D.

February 23, 2012

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I. INTRODUCTION

A. Qualifications

1. My name is James Levinsohn, and I am the Charles W. Goodyear Professor of Global Affairs at Yale University. I am a Professor of Economics at the Yale School of Management, the founding Director of the Jackson Institute for Global Affairs at Yale, and a Research Associate of the National Bureau of Economic Research.

2. I received my Ph.D. in Economics from Princeton University in 1988. Prior to that I had also received an M.P.A. from the Woodrow Wilson School of Public and International Affairs at Princeton University in 1985 and a B.A. from Williams College in 1981. From 1988 through 2009, I was on the faculty of the University of Michigan. I have taught courses in Industrial Organization (Ph.D. level), International Economics (Ph.D., Masters, and undergraduate levels), Microeconomic Theory (Masters level), Development Economics (Ph.D. level), and Applied Econometrics (Masters level).

3. I have published in peer-reviewed journals and elsewhere on topics in industrial organization, applied econometrics, international trade theory and policy, as well as other areas. My published work includes papers on the econometric modeling of consumer choice among differentiated products, how firms set prices in oligopolistic markets, how antitrust and trade policy interrelate, and how firms in imperfectly competitive markets respond to regulation. Most of my academic research involves econometric analysis of microeconomic data, including work that addresses the econometric implications of unobserved product quality for the estimation of demand for differentiated products.[1]

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[1] See, for instance, Berry, Steven, James Levinsohn, and Ariel Pakes, "Automobile Prices in Market Equilibrium," *Econometrica*, Vol. 63(4), July 1995, pp. 841-890.

4. I am currently on the editorial boards of the *Journal of Economic Literature* and the *Review of Economics and Statistics*. I have served as the co-Editor of the *Journal of International Economics* and on the editorial board of the *American Economic Review*. In addition, I regularly serve as a referee for journals in many fields of economics.

5. I have consulted in antitrust-related and other business-related matters in several industries and have also consulted for several international organizations and governments. My expertise is described more extensively in the attached curriculum vitae and includes a list of the cases in which I have submitted expert testimony during the past four years (see Appendix A). I am being compensated at the rate of $750 per hour for my work in this case. I have also been assisted by others working under my direction on this report and have received compensation based on their fees. None of my compensation is contingent or in any way dependent on the nature of my findings, opinions and/or on the outcome of this litigation.

B. Allegations

6. The Plaintiffs allege that the defendant manufacturers formed a cartel to restrict competition and raise the prices of LCD panels over a period "extending from at least January 1, 1999 through at least December 31, 2006, at a minimum."[2,3,4,5]

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[2] Second Amended Complaint for Damages and Injunctive Relief, Demand for Jury Trial, 10-cv-4945 SI, No. 3:07-MD-1827 SI, MDL No. 1827, United States District Court, For the Northern District of California, San Francisco Division, September 9, 2011, pp. 2-4; Complaint and Jury Demand, Best Buy Co., Inc. et al., v. AU Optronics Corp. et al., No. 10 4572, United States District Court, Northern District of California, October 6, 2010, pp. 2-3; Complaint and Jury Demand, Costco Wholesale Corporation, v. AU Optronics Corp., et al., No. 2:10-cv-01939, United States District Court, Western District of Washington, at Seattle, November 30, 2010, pp. 2-3; Complaint, Electrograph Systems, Inc, and Electrograph Technologies, Corp., v. Epson Imaging Devices Corporation, et al., Case No. 09 4845, United States District Court, Eastern District of New York, November 6, 2009, pp. 2-3; Third Amended Complaint for Damages and Injunctive Relief, Demand for Jury Trial, In Re TFT-LCD (Flat Panel) Antitrust Litigation, This Document Relates to Case No. 09-cv-4997-SI, Master File No. 07-m-1827 SI, MDL No. 1827, United States District Court, Northern District of California, San Francisco Division, September 9, 2011, pp. 2-4; Third Amended Complaint for Damages and Injunctive Relief, Demand for Jury Trial, In Re TFT-LCD (Flat Panel) Antitrust Litigation, This Document Relates to Case No. 09-cv-5840-SI, Master File No. 07-m-1827 SI, MDL No. 1827, United States District Court, Northern District of California, San Francisco Division, July 22, 2011, pp. 2-4.

C. Assignment

7. A major focus of expert work in this matter is to evaluate whether, and to what extent, alleged overcharges on panels were passed on to the Plaintiffs, and whether the Plaintiffs, in turn, passed on any such overcharges to their downstream customers.[6]

8. I have been asked to address the following topics:

- The economics of pass-on;
- The econometrics of estimating pass-on rates;
- The reports of Professor B. Douglas Bernheim,[7] Professor Leslie Marx,[8] Dr. Gareth Macartney,[9] and Dr. Mohan Rao[10] as they relate to the econometric estimation of pass-on.

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3 First Amended Complaint, *Eastman Kodak Company v. Epson Imaging Devices Corporation et al.*, No. 3:07-MD-01827-SI, 3:10-cv-05452-SI, United States District Court, Northern District of California, San Francisco Division, December 1, 2010, pp. 1-2. The Plaintiff has claimed that it was overcharged on purchases of LCD panels including TFT-LCD panels, STN LCD panels and TFD-LCD panels.

4 Second Amended Complaint, *Dell Inc. and Dell Products L.P., v. Sharp Corporation et al.*, No. M:07-MD-1827 SI, MDL No. 1827, United States District Court, Northern District of California, San Francisco Division, August 8, 2011, pp. 1-2.

5 This report also pertains to the arbitration proceedings between certain Defendants and Costco Wholesale, Inc.

6 The extent to which a supplier adjusts the prices it charges in response to changes in the incremental costs of making those products is typically referred to as "pass-through" in the economics literature.

7 Expert Report of B. Douglas Bernheim, Ph.D. Concerning Target Corp., Sears, Roebuck and Co., Kmart Corp., Old Comp Inc., Good Guys, Inc., RadioShack Corp. and Newegg Inc., and Supporting Materials, *In Re: TFT-LCD (Flat Panel) Antitrust Litigation*, No. 10-cv-4945-SI, Master File No. 07-m-1827 SI, MDL No. 1827, United States District Court, Northern District of California, San Francisco Division, December 15, 2011.

Expert Report of B. Douglas Bernheim, Ph.D. Concerning Overcharges to Costco Wholesale Corporation on Products Containing LCD Panels, Errata and Updates, and Supporting Materials, *In Re: TFT-LCD (Flat Panel) Antitrust Litigation*, No. 3:11-00058 SI, Master File No. M:07-1827 SI-FS, MDL No. 1827, United States District Court, Northern District of California, San Francisco Division, December 15, 2011.

Expert Report of B. Douglas Bernheim, Ph.D. Concerning Motorola Mobility, Inc, and Supporting Materials, *In Re: TFT-LCD (Flat Panel) Antitrust Litigation*, No. 09-cv-5840-SI, Master File No. 07-m-1827-SI, MDL

The materials that I have relied upon in conducting my analysis are listed in Appendix B.

D. Summary of Principal Opinions and Conclusions

9. I have reached the following principal opinions and conclusions:

No. 1827, United States District Court, Northern District of California, San Francisco Division, December 15, 2011.

Expert Report of B. Douglas Bernheim, Ph.D. Concerning Electrograph Systems, Inc. and Electrograph Technologies Corp., and Supporting Materials, *In Re: TFT-LCD (Flat Panel) Antitrust Litigation*, No. 3:10-cv-00117 SI, Master File No. M:07-md-1827 SI-FS, MDL No. 1827, United States District Court, Northern District of California, San Francisco Division, December 15, 2011.

Expert Report of B. Douglas Bernheim, Ph.D. Concerning Best Buy Co, Inc., et al., Errata and Updates, and Supporting Materials, *In Re: TFT-LCD (Flat Panel) Antitrust Litigation*, No. 3:10-cv-4572 SI, Master File No. M:07-MD-1827 SI-FS, MDL No. 1827, United States District Court, Northern District of California, San Francisco Division, December 15, 2011.

8 Expert Report of Leslie M. Marx, Ph.D., Concerning Target Corp., Sears, Roebuck and Co., Kmart Corp., Old Comp Inc., Good Guys, Inc., RadioShack Corp. and Newegg Inc, Errata, and Supporting Materials, *In Re: TFT-LCD (Flat Panel) Antitrust Litigation*, No. 10-cv-4945-SI, Master File No. 07-m-1827 SI, MDL No. 1827, United States District Court, Northern District of California, San Francisco Division, December 15, 2011.

Expert Report of Leslie M. Marx, Ph.D., Concerning Electrograph Systems, Inc. and Electrograph Technologies Corp., and Supporting Materials including Supplement, *In Re: TFT-LCD (Flat Panel) Antitrust Litigation*, No. 3:10-cv-00117 SI, Master File No. M:07-md-1827 SI-FS, MDL No. 1827, United States District Court, Northern District of California, San Francisco Division, December 15, 2011.

Expert Report of Leslie M. Marx, Ph.D. Concerning AT&T Mobility LLC, and Supporting Materials, *In Re: TFT-LCD (Flat Panel) Antitrust Litigation*, No. 09-cv-4997 SI, Master File No. 07-m-1827 SI, MDL No. 1827, United States District Court, Northern District of California, San Francisco Division, December 21, 2011.

9 Expert Report of Gareth Macartney, Ph.D., and Supporting Materials, *Eastman Kodak Company v. Epson Imaging Devices Corporation, et al.*, No. 3:10-CV-05452-SI, United States District Court, Northern District of California, San Francisco Division, December 15, 2011.

10 Expert Report of Mohan Rao, Ph.D., and Supporting Materials, *Dell Inc. and Dell Products L.P.*, *v. Sharp Corporation, et al.*, No. 10 1064, United States District Court, Northern District of California, San Francisco Division, December 15, 2011.

- As a matter of economic theory, the rate of pass-on can range from 0 percent to over 100 percent, depending on competitive conditions and the characteristics of the demand that a supplier faces. Fundamentally, pass-on is an empirical issue.
- An econometric approach designed to estimate the rate of pass-on by regressing price on cost that does not control for product quality and product life-cycle effects can be expected to result in an estimate of pass-on that is biased upward if (i) higher quality products cost more to make and are priced at higher margins or (ii) product demand weakens and cost falls over the life-cycle of a product.
- With the exception of Dr. Macartney's downstream pass-on specification, none of the econometric specifications Plaintiffs' experts offered control for both product quality and product life-cycle effects. Hence, these Plaintiffs' experts' estimates of pass-on should be expected to be biased upward.
- In any econometric estimation of pass-on, measurement error is a possibility, and the implications are context specific. Classical measurement error may cause attenuation bias in the estimated rate of pass-on, but steps can be taken to minimize its potential effects. Non-classical measurement error can cause upward or downward bias, depending on the specific problem. The effect of measurement error for the estimation of pass-on is ultimately an empirical question, and there should be no a priori presumption that any specific estimate is biased upward or downward by measurement error.

10. The outline for the rest of my report is as follows. In Section II, I discuss the issue of pass-on from the perspective of economic theory. In Section III, I discuss the econometric estimation of pass-on.

II. THE ECONOMICS OF PASS-ON

11. For a Plaintiff that purchased a finished product from a direct purchaser of a panel, the overcharge, if any, that the Plaintiff paid depends on: (1) the overcharge that the direct

purchaser paid on the panel and (2) the extent to which the direct purchaser then charged a higher price for its finished product *because* it paid a higher price for the panel.[11] I refer to this second factor as "pass-on."

12. As a matter of economic theory, the amount of a change in cost that a supplier passes on to its customers depends on the "shape" of the demand schedule the supplier faces.

- A supplier that faces a downward-sloped linear demand schedule, and has constant marginal cost, is expected to pass on 50 percent of a change in cost.
- A supplier that faces a downward-sloped convex demand schedule, and has constant marginal cost, is expected to pass on more than 50 percent of a change in cost. The amount by which the pass-on rate exceeds 50 percent depends on the convexity of the demand schedule.

A. A Supplier that Faces a Downward-Sloped Linear Demand Schedule Passes on 50 Percent of a Change in Cost

13. Figure 1 presents the case of a supplier that faces a downward-sloped linear demand schedule. The y-axis of the graph is price. The x-axis is quantity.[12]

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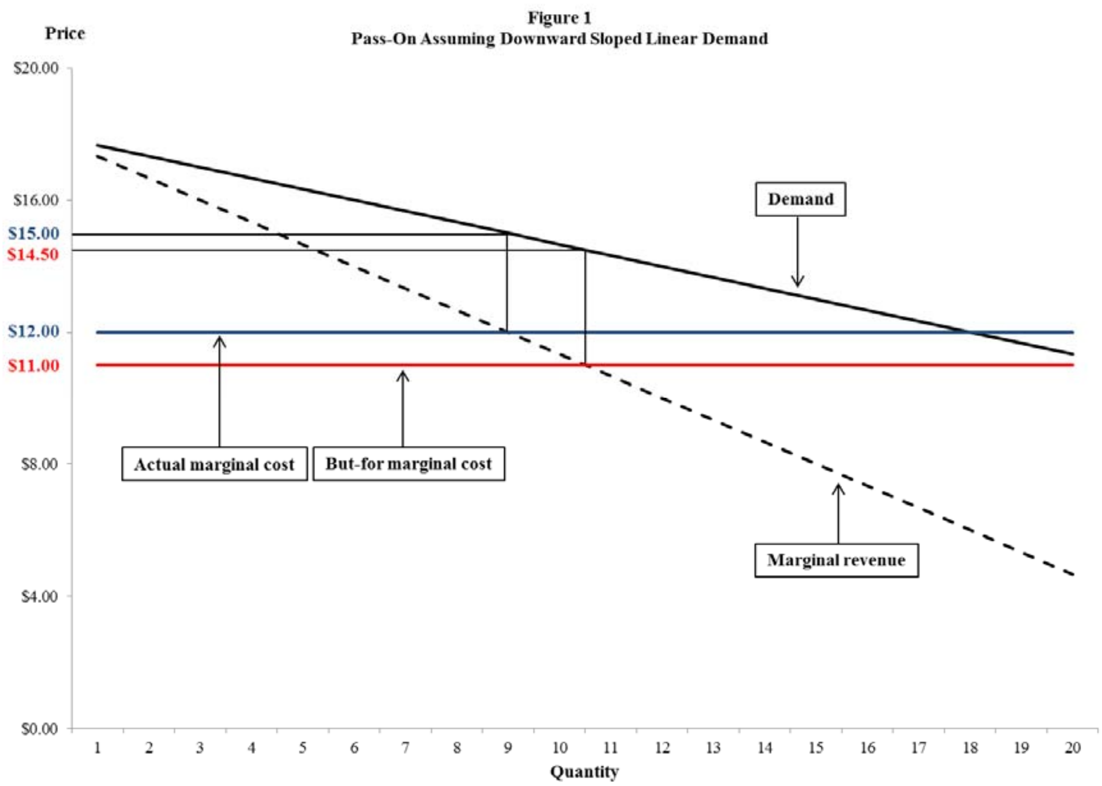
[11] Note that for a Plaintiff that purchased a finished product from an entity that was not a direct purchaser of a panel, the overcharge that the Plaintiff paid on that purchase would depend on (1) the overcharge that the direct purchaser paid on the panel, (2) the extent that the direct purchaser charged a higher price for the panel or for its finished product because it paid a higher price for the panel, and (3) the extent to which each of the entities between the direct purchaser of the panel and the Plaintiff in the distribution chain charged higher prices because they paid higher prices.

[12] In this example, demand (Q) is assumed to be a linear function of price (P): $Q = a - bP$. The total cost (TC) function is also assumed to be linear such that marginal cost (MC) is constant: $TC = c + dQ$ and $MC = d$.



14. The downward sloped solid and dashed black lines are the demand and marginal revenue schedules faced by the supplier of a given finished product. The demand schedule traces out the number of units of the finished product demanded by consumers at any given price. That the schedule is not horizontal (i.e., flat) reflects the fact that demand for the product does not completely go away when the supplier sets a slightly higher price.

15. The solid blue horizontal line is the supplier's actual marginal cost schedule. It traces out the additional cost to the supplier associated with producing one additional unit of the finished product. The schedule is flat, which reflects the assumption that the additional cost to the supplier of producing one additional unit does not depend on the number of

units that the supplier produces. In Figure 1, the profit maximizing price under the actual marginal cost schedule is $15.00.[13]

16. If the supplier paid an overcharge on an input, the actual marginal cost schedule would be artificially elevated, and so it would lie above the "but-for" marginal cost schedule. The level of the red horizontal line – the supplier's but-for marginal cost schedule – reflects this.

17. Assuming that the supplier had not paid an inflated price for the input, the intersection of the marginal revenue and but-for marginal cost schedules determines the but-for profit-maximizing quantity, and the but-for profit-maximizing price can be inferred from the demand schedule. In Figure 1, the but-for profit-maximizing price is $14.50.[14]

18. Thus, in this example, the supplier's marginal cost is $1 higher in the actual world than in the but-for world, and the price the supplier charges for the finished product is $0.50 higher in the actual world than in the but-for world. This means that the pass-on rate is 50 percent.[15]

19. Some intuition for this result is that when the supplier's marginal cost goes up, the supplier finds itself setting price on a portion of its demand schedule where demand is relatively sensitive to price (i.e., more elastic),[16] and a supplier will pass on a smaller amount of a cost increase when demand is more sensitive to price, all else equal.

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13 In Figure 1, demand is defined by the equation $Q = 54 - 3P$. Actual total cost is defined by the equation $TC=c+12Q$, where c is the firm's fixed cost.

14 But-for total cost is defined by the equation $TC=c+11Q$, where c is the firm's fixed cost.

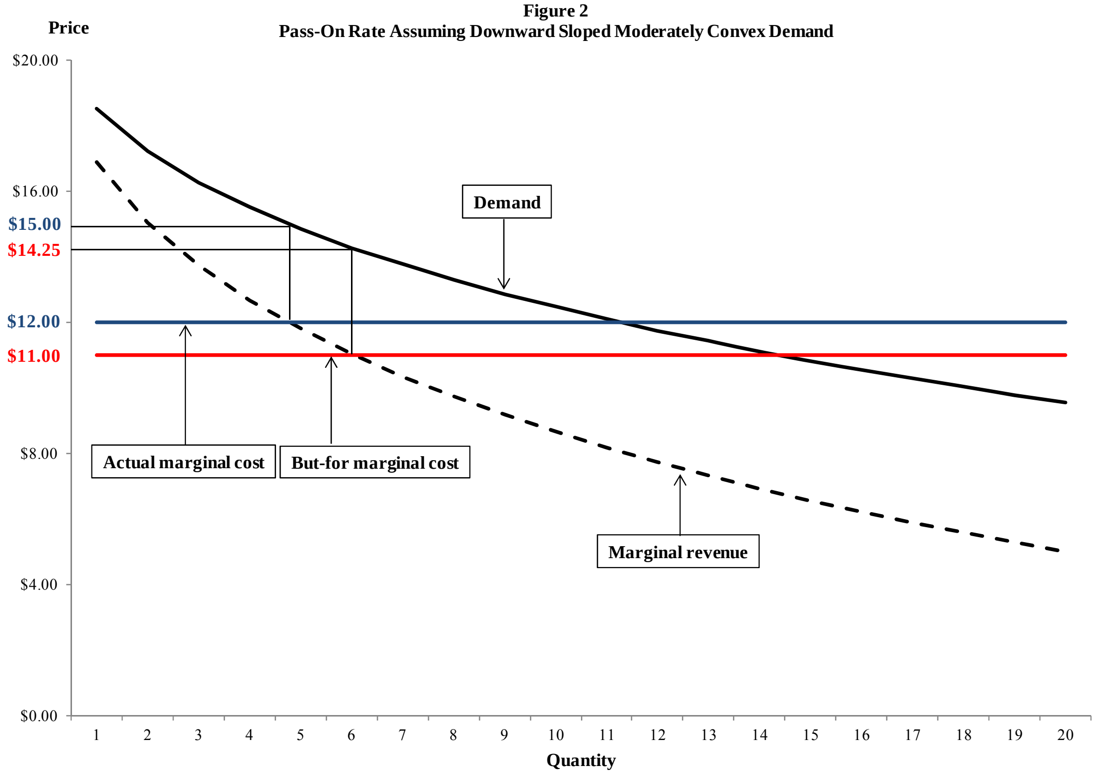
15 With a downward sloped linear demand schedule and constant marginal cost, the pass-on rate is 50 percent no matter what the elasticity of demand. This is not the case if marginal cost is not constant. In this case, the pass-on rate does depend on the elasticity of demand.

16 This is a feature of a linear demand schedule. The elasticity of demand is not constant. At higher prices, demand is relatively elastic. At lower prices, demand is relatively inelastic.

B. A Supplier that Faces a Downward-Sloped Convex Demand Schedule Passes on More Than 50 Percent of a Change in Cost

20. Figure 2 presents the case for a supplier that faces a downward-sloped, convex demand schedule.[17]

Figure 2
Pass-On Rate Assuming Downward Sloped Moderately Convex Demand



21. In Figure 2, the profit maximizing price with the actual marginal cost schedule is $15.00 while the but-for profit maximizing price is $14.25.[18] Thus, in this example, the supplier's

[17] In this example, demand is assumed to take the Box-Cox functional form. This Box-Cox specification is a generalization of the linear demand case. While the linear demand function is Q = a – bP, the Box-Cox function is $\frac{Q^{\lambda}-1}{\lambda} = a' - b\left(\frac{P^{\lambda}-1}{\lambda}\right)$. The parameter λ allows for the demand schedule to exhibit curvature. When λ=1, the demand schedule is linear, as in Figure 1; when λ<1, the demand schedule is curved, as in Figure 2. See Kosicki, George, and Miles B. Cahill, "Economics of Cost Pass Through and Damages in Indirect Purchaser Antitrust Cases," *The Antitrust Bulletin*, Vol. 51(3), Fall 2006, pp. 614-615.

marginal cost is $1 higher in the actual world than in the but-for world, and the price the supplier charges for the finished product is $0.75 higher in the actual world than in the but-for world. This means that, in this example, the pass-on rate is 75 percent.

22. In the case of a supplier that faces a downward-sloped linear demand schedule, the intuition for why the supplier does not pass on all of an increase in cost is that the cost increase moves the supplier to a region of the demand schedule where demand is more sensitive to price. For a supplier that faces a downward-sloped convex demand schedule, this effect is less pronounced – the cost increase moves the supplier to a region of the demand schedule where demand is more sensitive to price, but the move is less dramatic than the case of the supplier that faces a downward-sloped linear demand schedule.

23. Figure 3 presents the case for a supplier that faces a downward-sloped demand schedule that is even more convex than the demand schedule in Figure 2.

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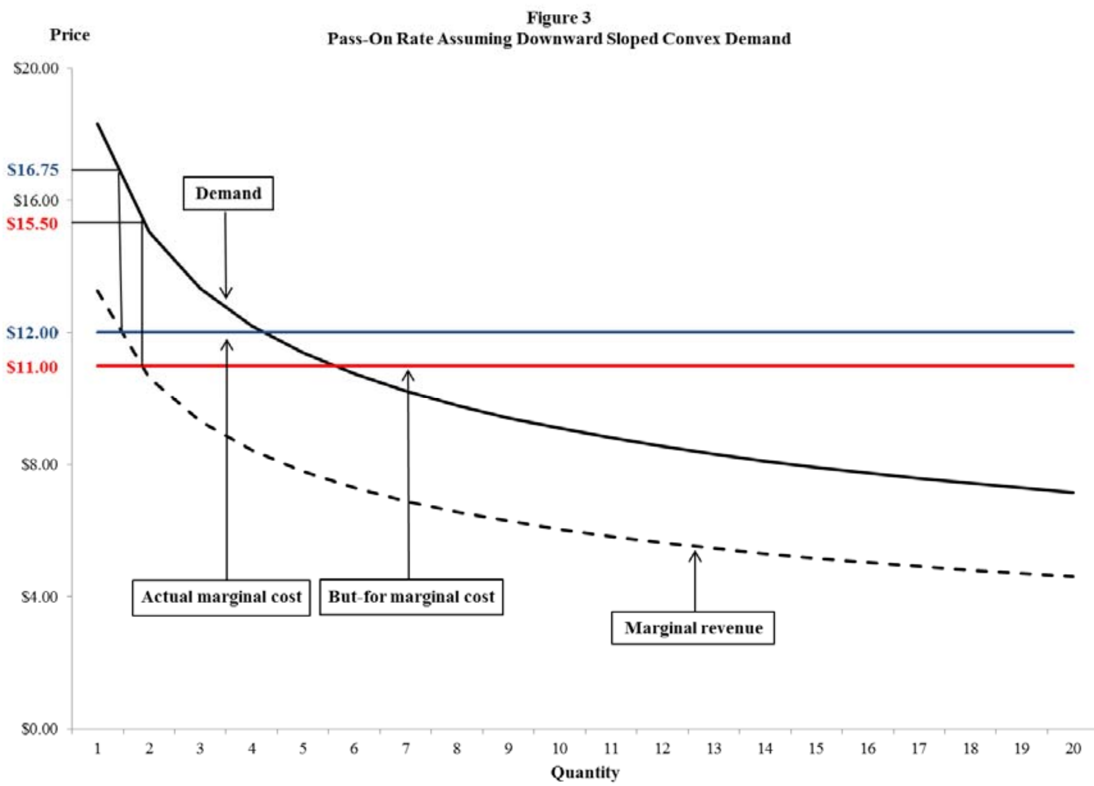
[18] In Figure 2, demand is defined by the equation: $\frac{Q^{0.46}-1}{0.46} = 18.15 - 2.95\left(\frac{P^{0.46}-1}{0.46}\right)$.



24. In Figure 3, the actual profit maximizing price with the actual marginal cost schedule is $16.75 while the but-for profit maximizing price is $15.50. Thus, in this example, the supplier's marginal cost is $1 higher in the actual world than in the but-for world, and the price the supplier charges for the finished product is $1.25 higher in the actual world than in the but-for world. This implies that, in this example, the pass-on rate is 125 percent. Again, the intuition for this result is that the increase in cost moves the supplier to a region of the demand schedule where demand is relatively sensitive to price, but as the demand schedule becomes more convex, this change in the sensitivity of demand to price is smaller, which allows the supplier to pass on a larger amount of the cost increase.[19]

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19 In Figure 3, demand is defined by the equation: $\frac{Q^{0.065}-1}{0.065} = 9.602 - 3\left(\frac{P^{0.065}-1}{0.065}\right)$.

C. Summary

25. The amount of an input cost increase that a supplier passes on to its customers depends on the characteristics of the demand that the supplier faces. When the supplier faces demand that is more sensitive to price at higher prices, the supplier passes on less of an input cost increase, all else equal. For practical purposes, this has the following implication: absent detailed information about the "shape" of the demand schedule that a supplier faces, the amount of an input cost increase that a supplier passes on cannot be determined, a priori. As such, pass-on is fundamentally an empirical issue.

III. EMPIRICAL ANALYSIS OF PASS-ON

A. Product Quality and Product Life-Cycle Effects Should Be Controlled For in an Econometric Model of Pass-On

26. In the simplest case, pass-on for a given firm can be estimated econometrically by running a linear regression of the price of product i in period t, P_{it}, on the cost of product i in period t, C_{it}.[20] The estimating equation in this case is given by:

(1) $$P_{it} = \alpha + \beta C_{it} + \varepsilon_{it}.$$

27. In equation (1), the estimate of pass-on is β and ε_{it} represents all unmodeled factors that impact price other than cost. For the estimate of β to be unbiased, ε_{it} must be uncorrelated with the included regressor C_{it} – the cost of the product.

28. For the case of finished products that contain LCD panels ("finished LCD products"), there are two key conceptual reasons why cost might be correlated with the error term in equation (1). The first applies to the cross-sectional variation in the data. That is, how product quality at a given point in time varies across products. The second applies to the

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[20] Here and in what follows below, I assume that firm-specific data are available on the prices and costs of I products that are produced and sold over a maximum of T periods, where the price of product i, $i \in \{1,2,...I\}$, at period t, $t \in \{1,2,...T\}$, is denoted as P_{it}, and the corresponding cost is denoted as C_{it}.

time-series variation in the data. That is, how a given product's price and cost vary at different points over time. I discuss each in turn.

29. Like many "high–tech" products, some finished LCD products are higher "quality" than others. For example, a laptop with more memory, a larger hard drive, and a faster microprocessor is considered to be of higher quality than a laptop with less memory, a smaller hard drive, and a slower microprocessor. Product quality affects price, and is not modeled in equation (1), which means that it is in the error term, ε_{it}. Some of the effect of product quality on price operates through the relationship between product quality and product cost. Higher quality products typically cost more to produce[21] and, to a certain extent, their prices reflect this. But some of the effect of product quality on price can be distinct from the relationship between product quality and cost, which means that higher quality products may be priced at higher price/cost margins than lower quality products.[22]

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21 See, for example, Weifang Lou, David Prentice, Xiangkang Yin, "What Difference Does Dynamics Make? The Case of Digital Cameras," *International Journal of Industrial Organization*, 30, 2012, pp. 30 – 40 at p. 35 ("[I]t is generally more costly for firms to produce cameras with more robust material and extra components, confirming that the weight signals some favored unobservable components or quality of a camera.")

22 One form of price discrimination occurs when a firm with market power sells different versions of a given product to take advantage of differences in consumers' willingness to pay for product quality. Firms offer a menu of products and prices, each of which is targeted toward a specific type of consumer, where the products are designed in a way that makes it optimal for consumers of each type to choose the product that is designed for them. See, for example, Jean Tirole, *The Theory of Industrial Organization*, The MIT Press, 1997, pp. 142-143, 149-150.

Mussa and Rosen (1978), for example, show how a monopolist can extract higher profit margins from consumers with a higher willingness to pay for quality by offering a wide product line of price-quality combinations. (Michael Mussa and Sherwin Rosen, "Monopoly and Product Quality," *Journal of Economic Theory*, Vol. 18(2), 1978, pp. 301-317.)

Deltas et al. (2011), for example, find that (i) computer prices are higher for a firm's "flagship" products (highest speed computers), even after accounting for the direct effect of higher performance on price; (ii) that for computers with any particular computer chip, prices are systematically higher the closer the computers are to the firm's "frontier," meaning that they are the highest-end product of a firm's product line; and (iii) that firms earn rents for their high quality products, while prices for products of lower quality are nearly perfectly competitive, meaning that competition is stronger for low rank/quality products than for high quality products. (George Deltas, Thanasis Stengos and Eleftherios Zacharies, "Product Line Pricing in a Vertically Differentiated Oligopoly," *Canadian Journal of Economics*, Vol. 44, 2011, pp. 907-929.)

30. An implication is that the error term ε_{it} in equation (1) is (positively) correlated with the included regressor C_{it} – the cost of the product. In the presence of unmodeled product quality that is positively correlated with product cost and margin, estimates of pass-on can be expected to be biased upward.

31. There is a very simple solution to control for the effects of product quality that are unobserved by the econometrician and not already controlled for by observed cost. The inclusion of an indicator variable for each product, also termed a product-level fixed effect, will control for differences in quality across products that do not vary over time. This implies an estimating equation given by:

(2) $$P_{it} = \alpha + \beta C_{it} + \delta_i + \varepsilon_{it}$$

where P_{it} is the price of product *i* at calendar time *t*, C_{it} is the cost of product *i* at calendar time *t*, and δ_i is a product-level fixed effect.[23]

32. Equation (2) controls for unobserved product quality, and is an improvement over equation (1), but may still yield biased estimates of pass-on. This is because product life-cycles are not modeled in equations (1) or (2). This has important implications for the estimation of pass-on.

Shepard (1999), for example, finds that retail gas stations that offer both full-service (high-quality) and self-service (low quality) charge higher prices for full-service (high-quality) than full-service-only gas stations and lower prices for self-service (low quality) than self-service-only gas stations. This is consistent with price discrimination and profit margins that are higher for the high-quality product than the low-quality product. (Andrea Shepard, "Price Discrimination and Retail Configuration," *The Journal of Political Economy*, Vol. 99, No. 1, Feb. 1991, pp. 30-53.)

Verboven (2002), for example, argues that cars with diesel engines can be considered to be of higher quality than cars that run on gasoline because of the lower cost of diesel fuel and favorable tax treatment, and finds that the higher quality product (diesel-engine cars) sell at higher margins than the lower quality products (gasoline-engine cars). (Frank Verboven, "Product Line Rivalry and Market Segmentation, with an Application to Automobile Optional Engine Pricing," *Journal of Industrial Economics*, 47, pp. 399-425.)

23 Inclusion of the product-level fixed effect in equation (2) allows the intercept in the model to be different for every product, $i \in \{1,2,\ldots I\}$.

33. Like many high-tech products, finished LCD products have life-cycles.[24] Three important changes tend to occur over these life-cycles. One, when a new finished LCD product is introduced, it is more likely to be state-of-the-art and it tends to be priced high. As new and improved finished LCD products are subsequently introduced, the demand for a given product tends to fall.[25] Two, when a new finished LCD product is introduced, the type of customer purchasing the product is more likely to be an "early adopter" who is less price elastic.[26,27] Over the life-cycle of the product, the type of customer purchasing the product

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24 See, for example, Weifang Lou, David Prentice, Xiangkang Yin, "What Difference Does Dynamics Make? The Case of Digital Cameras," *International Journal of Industrial Organization*, 30, 2012, pp. 30 – 40 at p. 30. ("New products entering into and old products retiring from markets is a prevailing phenomenon. It is more noticeable in markets where there is rapid technological change and product prices fall steeply and persistently. Examples of such markets include consumer electronics like personal computers, television sets, mobile phones, digital camcorders and digital cameras.")

25 See, for example, Barak Y. Orbach, "The Durapolist Puzzle: Monopoly Power in Durable-Goods Markets," *Yale Journal on Regulation*, 21, 2004, pp. 67 – 118 at p. 89. ("In the real world … a declining price trajectory is a profitable and extremely ordinary strategy among durapolists. Many new products, like books and consumer electronics, are very expensive when they first appear on the market; over time, their prices decline. In many cases, prices go down with the appearance of newer products that undermine the appeal of older products.")

26 See, for example, Robert S. Pindyck and Daniel S. Rubinfeld, *Microeconomics*, 7th Edition, p.403. ("The objective of intertemporal price discrimination is to divide consumers into high-demand and low-demand groups by charging a price that is high at first but falls later. To see how this strategy works, think about how an electronics company might price new, technologically advanced equipment, such as high-performance digital cameras or LCD television monitors… The strategy, then, is to offer the product initially at the high price P_1, selling mostly to consumers [whose demand is less elastic]. Later, after this group of consumers has bought the product, the price is lowered to P_2, and sales are made to the larger group of consumers [for whom demand is more elastic].")

27 See, for example, Barak Y. Orbach, "The Durapolist Puzzle: Monopoly Power in Durable-Goods Markets," *Yale Journal on Regulation*, 21, 2004, pp. 67 – 118, at pp. 89-90. ("[T]he decline [in prices over time] constitutes intertemporal price discrimination: Early shoppers are charged more than late shoppers. Indeed, a declining price path may be a well-crafted strategy of durapolists rather than time-inconsistent behavior. When such a strategy is properly devised, the durapolist's profits are higher than under a regime of a constant monopoly price. A planned declining price trajectory, often referred to as *price skimming*, is based on price discrimination among consumers according to their price-time sensitivity. Time-sensitive consumers are willing to pay premia to receive products immediately. Such consumers know that prices will decline but, nevertheless, are too impatient to postpone purchases. In contrast, price-sensitive consumers are unwilling to pay the premia charged early shoppers, so they delay purchases until prices are low. Recognizing the existence of different sets of consumers, a durapolist can maximize profits by pursuing a declining price path.") Related

changes and becomes more price elastic. This is another reason why the price of a given product tends to fall over the product life-cycle. Three, when a new finished LCD product is introduced, it generally costs more to produce. As better production techniques are developed and product yields increase, costs tend to fall.[28]

34. The well-understood and common pattern of prices and costs described above has implications for the estimation of pass-on. Over the life-cycle of a product, demand weakens, which leads to price decreases. This phenomenon shows up in equation (2) as a negative "shock" embodied in ε_{it}. This weakening of demand coincides with – is correlated with – decreases in the cost of making the product. But in specifying equation (2), the econometrician assumes that weakening of demand over the life-cycle of a product is uncorrelated with decreases in cost over the life-cycle. By making this assumption, the estimate of pass-on from equation (2) can be expected to be biased upward, meaning that the estimated rate of pass-on when product life-cycles are ignored is likely to be higher than the true rate of pass-on.

35. This product life-cycle effect can be accounted for by controlling for the amount of time that a product has been on the market. (I denote the amount of time that a product has been on the market by the subscript *a*.) This can be done by including a time-on-market fixed effect. Hence, equation (2) becomes:

(3) $$P_{iat} = \alpha + \beta C_{iat} + \delta_i + \gamma_a + \varepsilon_{iat}$$

issues are discussed in Ying Zhao, "Why Are Prices Falling Fast? An Empirical Study of the US Digital Camera Market," Working Paper, November 2006.

28 See, for example, Robert S. Pindyck and Daniel S. Rubinfeld, *Microeconomics*, 7th Edition, p. 403, footnote 9. ("The prices of new electronics products also come down over time because costs fall as producers start to achieve greater scale economies and move down the learning curve. But even if costs did not fall, producers can make more money by setting high prices and then reducing them over time, thereby discriminating and capturing consumer surplus.")

where P_{iat} is the price of product i in period a, $a \in \{1,2,\ldots A\}$, of its life-cycle at calendar time t, C_{iat} is the cost of product i in period a of its life-cycle at calendar time t, δ_i is the product-level fixed effect defined in equation (2), and γ_a is a time-on-market fixed effect.[29] Both δ_i and γ_a are parameters to be estimated in equation (3).

36. The econometric specification in equation (3) controls for product quality and includes a control for the amount of time that a product has been on the market, but still may yield biased estimates of pass-on. The parameters γ_a control for a product life-cycle effect that is common to all products. This is a restriction because product life-cycle effects may differ across products. Demand can fall over the product life-cycle in ways that are not uniform across products. For example, products that are more innovative may experience more substantial relative decreases in demand over their life-cycles compared to products that are less innovative. One reason is that a more innovative product will typically be purchased early in the product life-cycle by "early adopters" who are less price elastic and then later in the product life-cycle by "later adopters" who are more price elastic; a less innovative product will typically be purchased by "later adopters" who are more price elastic over the entire life-cycle. The more substantial weakening of demand for the more innovative product can result in more substantial decreases in prices over the product life-cycle. Products that are more innovative may also experience more substantial decreases in cost over the life-cycle compared to products that are less innovative. One reason is that the learning effects can be more substantial for the more innovative products compared to the less innovative products. An implication is that product-specific life-cycle effects may not be fully controlled for by the common time-on-market fixed effect in equation (3), which could cause the estimate of pass-on to be biased.

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29 Inclusion of the time-on-market fixed effect in equation (3) allows the intercept in the model to change with the number of periods that a product is on the market.

37. In principle, this could be addressed by including a separate set of product-specific indicator variables for the amount of time a product has been on the market:

(4) $$P_{iat} = \alpha + \beta C_{iat} + \lambda_{ia} + \varepsilon_{iat}$$

where P_{iat} is the price of product *i* in period *a* of its life-cycle at calendar time *t*, C_{iat} is the cost of product *i* in period *a* of its life-cycle at calendar time *t*, and λ_{ia} is a time-on-market effect for product *i* in period *a* of its life-cycle.[30]

38. As a practical matter though, equation (4) cannot be estimated. The number of parameters that are required – the set of product-specific time-on-market parameters – is greater than the number of observations in the data.

39. Instead, the specification in equation (4) can be approximated by replacing the product-specific time-on-market parameters (i.e., the λ_{ia}) with a linear time-on-market trend:

(5) $$P_{iat} = \alpha + \beta C_{iat} + \delta_i + \theta_i a + \varepsilon_{iat}$$

40. In specification (5), the time-on-market trend is denoted by "a" and takes the value of the total number of periods that the product has been on the market. As already defined in equation (3), P_{iat} and C_{iat} are the price and cost of product *i* when product *i* has been on the market for *a* periods. The parameter θ_i allows the time-on-market trend to be product-specific.[31]

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30 Inclusion of the product-specific time-on-market fixed effect in equation (4) allows the intercept to be different for every product – time-on-market combination. For example, $\alpha + \lambda_{21}$ is the intercept for product *2* in its first period on the market.

31 Inclusion of the parameter θ_i is equivalent to including a separate slope parameter for time-on-market for every specific product.

41. This model restricts product life-cycle effects to be linear, but allows them to vary across products, and can be estimated in two steps.[32] In step 1, the product fixed effect δ_i can be removed by differencing the data. Hence, equation (5) becomes:

(6) $$\Delta P_{iat} = \beta \Delta C_{iat} + \theta_i + \Delta \varepsilon_{iat} ,$$

where ΔP_{iat} is the difference in the price of product *i* between periods *a* and *a-1*of its life-cycle, ΔC_{iat} is the difference in the cost of product *i* between periods *a* and *a-1* of its life-cycle, and θ_i is the product-specific time-on-market parameter defined in equation (5).[33] In step 2, equation (6) can be estimated by differencing the data again or as a fixed effects model.[34]

42. In summary, the econometric specification in equation (6) controls for product quality and product-specific life-cycle effects. And while the sign of bias in any given specification is ultimately an empirical question – as an econometric matter, it depends on the signs of the various covariances – it is clear that ignoring product quality or product life-cycle effects may well bias the estimates of pass-on. Equation (6) addresses both the (typically upward) bias that results from ignoring that higher quality products are typically more costly to produce and may be priced at higher margins as well as the (again, typically upward) bias that results from ignoring product life-cycles.

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32 See, for example, Jeffrey M. Wooldridge, *Econometric Analysis of Cross Section and Panel Data*, The MIT Press, 2002, pp. 315-317.

33 Note that the period-to-period difference in the value taken by *a* for a given product is always equal to 1.

34 Note that in differencing equation (5), one time period is lost for every product, so that equation (6) applies to T-1 time periods. To difference equation (6) or estimate a fixed effects model using equation (6) requires T-1≥2 or T≥3 time periods for each product. In practice, if product life-cycles tend to be short, estimation of equation (6) may result in the exclusion of an unreasonably large number of products. An option is to restrict the time-on-market control in equation (6) to be common across all products. This would yield the following model: $\Delta P_{iat} = \beta \Delta C_{iat} + \theta + \Delta \varepsilon_{iat}$.

B. With One Exception - The Econometric Specifications Offered by Plaintiffs' Experts Do Not Control for Both Product Quality and Product Life-Cycles

i. Section Overview

43. In this section, I explain how the reports submitted by various Plaintiffs' experts address the econometric issues discussed above. I show how the various Plaintiffs' experts each estimate equations that are essentially restricted versions of either equation (5) or equation (6), and how only one specification offered by the Plaintiffs' experts controls for both product quality and product life-cycles.

44. Professor Bernheim, Professor Marx, Dr. Macartney, and Dr. Rao offer a collection of econometric specifications of pass-on. These are summarized below in Table 1 (square brackets represent error terms; additional notation will be explained in subsequent subsections).

Table 1. Comparison of Pass-On Specifications

Econometric Specifications of Pass-On			Controls For: Product Quality	Controls For: Product Life-Cycle
		$P_{iat} = \alpha + \beta C_{iat} + \delta_i + \theta_i a + \varepsilon_{iat}$	Yes	Yes
Professor Bernheim, Professor Marx, Dr. Macartney and Dr. Rao				
[A]	Bernheim[1] Marx[2]	$\overline{P}_i = \alpha + \beta \overline{C}_i + [\delta_i + \theta_i \overline{a}_i + \overline{\varepsilon}_i]$	No	No
[B]	Bernheim[3]	$\overline{P}_i = \alpha + \beta \overline{C}_i + \rho_d + [(\delta_i - \rho_d) + \theta_i \overline{a}_i + \overline{\varepsilon}_i]$	No	No
[C]	Bernheim[4]	$\overline{P}_i = \alpha + \beta \overline{C}_i + \sum_{t=1}^{T} \tau_t \frac{q_{it}}{q_i} + \rho_d + \left[(\delta_i - \rho_d) + \theta_i \overline{a}_i - \sum_{t=1}^{T} \tau_t \frac{q_{it}}{q_i} + \overline{\varepsilon}_i\right]$	No	No
[D]	Bernheim[5] Marx[6]	$P_{iat} = \alpha + \beta C_{iat} + \delta_i + [\theta_i a + \varepsilon_{iat}]$	Yes	No

[E]	Macartney[7] (upstream)	$ln(P_{iat}) = \alpha + \beta_1 ln(c_{it}) + \delta_i + \beta_2 ln(w_t) + \beta_3 ln(s_t) + [\theta_i a + (\beta_1(ln(C_{iat}) - ln(c_{it})) - \beta_2 ln(w_t) - \beta_3 ln(s_t)) + \varepsilon_{iat}]$	Yes	No
[F]	Macartney[8] (downstream)	$ln(P_{iat}) = \alpha + \beta ln(C_{iat}) + \delta_i + \varphi a + [\theta_i a - \varphi a + \varepsilon_{iat}]$	Yes	Yes
[G]	Rao[9]	$\Delta P_{iat} = \beta_1 \Delta c_{it-1} + \beta_2 \Delta x_t + [\theta_i - \beta_2 \Delta x_t + \beta_1 (\Delta C_{iat} - \Delta c_{it-1}) + \Delta \varepsilon_{iat}]$	Yes	Incomplete

Notes:

1. Corresponds to equation (4) on page 71 of the Bernheim Target et al. report for a given manufacturer.
2. Corresponds to equation (1) on page 16 of the Marx Target et al. report for a given Plaintiff.
3. Corresponds to equation (6) on page 73 of the Bernheim Target et al. report for a given manufacturer.
4. Corresponds to equation (8) on page 75 of the Bernheim Target et al. report for a given manufacturer.
5. Corresponds to equation (10) on page 76 of the Bernheim Target et al. report for a given manufacturer.
6. Corresponds to equation (3) on page 18 of the Marx Target et al. report for a given Plaintiff.
7. Corresponds to results presented in Table 15 on page 73 of the Macartney report.
8. Corresponds to results presented in Table 17 on page 76 of the Macartney report.
9. Corresponds to results presented in Tab 31 of the Rao report.

45. Each of the Plaintiffs' experts' specifications is a restricted version of the model described in equation (5), and only one controls for both product quality and product life-cycles:

- Professor Bernheim and Professor Marx estimate the specification shown in row [A] of Table 1.[35] This specification does not control for product quality or product

[35] Professor Bernheim estimates six regressions based on his equation (4), one per product application (televisions, monitors, notebooks, mobile phones, digital cameras, and camcorders). Each regression uses data from manufacturers and includes manufacturer-specific intercepts and cost coefficients. The estimated coefficients for the model shown in row [A] of Table 1 are equivalent to the estimated coefficients for each manufacturer in the model that Professor Bernheim estimates. Professor Bernheim also estimates versions of this model in which he restricts the cost coefficient to be the same across all manufacturers, but includes manufacturer-specific intercepts.

Professor Marx estimates one regression for mobile phones based on her equation (1). The regression uses purchase data from Plaintiffs and cost data from Motorola and includes Plaintiff-specific intercepts and cost coefficients. The estimated coefficients for the model shown in row [A] of Table 1 are equivalent to the estimated coefficients for each Plaintiff in the model that Professor Marx estimates. Professor Marx also estimates a version of this model in which she restricts the cost coefficient to be the same across all Plaintiffs, but includes Plaintiff-specific intercepts.

life-cycle effects. The estimates of pass-on from this specification can be expected to be biased upward if a manufacturer's higher quality products cost more to make and are priced at higher margins.

- Professor Bernheim estimates the specification shown in row [B] of Table 1.[36] This specification does not control for product quality within "product categories" or product life-cycle effects. The estimate of pass-on from this specification can be expected to be biased upward if, within "product categories," a manufacturer's higher quality products cost more to make and are priced at higher margins.
- Professor Bernheim estimates the specification shown in row [C] of Table 1.[37] This specification does not control for product quality within "product categories" or product life-cycle effects. The estimate of pass-on from this specification can be expected to be biased upward if, within "product categories," a manufacturer's higher quality products cost more to make and are priced at higher margins.

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36 Professor Bernheim estimates five regressions based on his equation (6), one per product application (televisions, monitors, notebooks, mobile phones, and digital cameras). Each regression uses data from manufacturers and includes manufacturer-specific intercepts and cost coefficients as well as "product category" fixed effects. The estimated coefficients for the model shown in row [B] of Table 1 are equivalent to the estimated coefficients for each manufacturer in the model that Professor Bernheim estimates. Professor Bernheim also estimates five versions of this model in which he restricts the cost coefficient to be the same across all manufacturers, but includes manufacturer-specific intercepts implicitly through the product category fixed effects.

37 Professor Bernheim estimates five regressions based on his equation (8), one per product application (televisions, monitors, notebooks, mobile phones, and digital cameras). Each regression uses data from manufacturers and includes manufacturer-specific intercepts and cost coefficients, "product category" fixed effects, and a set of controls that purport to control for the points in time during which particular products were sold. Professor Bernheim constrains the time period controls to be the same across manufacturers and so the specification shown in row [C] of Table 1 is a slightly more general version of the model that Professor Bernheim estimates. None of my conclusions about Professor Bernheim's specification in his equation (8) are affected by this. Professor Bernheim also estimates five versions of this model in which he restricts the cost coefficient to be the same across all manufacturers, but includes manufacturer-specific intercepts implicitly through the product category fixed effects.

- Professor Bernheim, Professor Marx, and Dr. Macartney (upstream) estimate the specifications shown in rows [D] and [E] of Table 1.[38] These specifications do not control for product life-cycle effects. The estimates of pass-on from this specification can be expected to be biased upward if product demand weakens and cost falls over the product life-cycle.

- Dr. Macartney estimates the specification shown in row [F] of Table 1 in his downstream analysis.[39] This specification controls for product quality and product life-cycle effects. This is the only specification offered by the Plaintiffs' experts that attempts to control for both of these factors. Notably, Dr. Macartney controls for product life-cycle effects in his analysis of downstream pass-on but not in his analysis of upstream pass-on. No explanation is given for this apparent inconsistency.

- Dr. Rao estimates the specification shown in row [G] of Table 1.[40] This specification controls for product quality and includes proxies for demand shifters

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[38] Professor Bernheim estimates six regressions based on his equation (10), one per product application (televisions, monitors, notebooks, mobile phones, digital cameras, and camcorders). Each regression includes manufacturer-specific intercepts and cost coefficients as well as product fixed effects. The estimated coefficients for the model shown in row [D] of Table 1 are equivalent to the estimated coefficients for each manufacturer in the model that Professor Bernheim estimates. Professor Bernheim also estimates three versions of this model in which he restricts the cost coefficient to be the same across all manufacturers.

Professor Marx estimates one regression for mobile phones based on her equation (3). The regression uses purchase data from Plaintiffs and cost data from Motorola and includes Plaintiff-specific intercepts and cost coefficients as well as mobile phone model fixed effects. The estimated coefficients for the model shown in row [D] of Table 1 are equivalent to the estimated coefficients for each Plaintiff in the model that Professor Marx estimates. Professor Marx also estimates a version of this model in which she restricts the cost coefficient to be the same across all Plaintiffs.

Dr. Macartney estimates one regression using the model shown in row [E] of Table 1 for digital cameras.

[39] Dr. Macartney estimates one regression using the model shown in row [F] of Table 1 for digital cameras.

[40] Dr. Rao estimates five specifications using the model shown in row [G] of Table 1 for Dell computer monitors. Dr. Rao's primary specification is estimated using quarterly price and cost data, where the cost data are DisplaySearch data on panel costs, lagged by one quarter. The next two specifications augment this

(GDP in one specification and the Price Index for Personal Consumption Expenditures for Personal Computers in another). These proxies may be only weakly correlated with changes in demand over the life-cycle of a Dell computer monitor though, in which case they would not adequately control for product life-cycle effects.

ii. Plaintiffs' Experts' Pass-On Specifications

46. I now show algebraically how each of the Plaintiffs' experts' specifications summarized in Table 1 can be derived from equation (5) by restricting product quality to be the same across products or by restricting the product life-cycle effects to be zero.

a. Professor Bernheim's Equation 4 and Professor Marx's Equation 1

47. The specification shown in row [A] of Table 1 regresses a measure of the average price of a product on a measure of the average cost of manufacturing the product:

(7) $$\overline{P}_i = \alpha + \beta \overline{C}_i + \overline{u}_i,$$

where $\overline{P}_i$ is the weighted average price and $\overline{C}_i$ is the weighted average cost of product *i* calculated over the lifespan of product *i*.

48. This regression can be derived from the model of pass-on in equation (5) by setting the product fixed effects and product life-cycle effects to be zero:

[R1] $\delta_i = 0$, for all *i*.

[R2] $\theta_i = 0$, for all *i*.

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specification by introducing a control for the change in GDP for OECD countries, lagged by one quarter and by introducing a control for the Price Index for Personal Consumption Expenditures for Personal Computers (PCE), lagged by one quarter. Dr. Rao also includes two sensitivity analyses, using data on internal panel prices from Samsung and LG. Without loss of generality, I discuss the specifications that control for the change in GDP for OECD countries or for the change in the PCE.

49. These two restrictions result in the following model:

(8) $$P_{iat} = \alpha + \beta C_{iat} + u_{iat}$$

50. Averaging the data across periods for each product yields:

(9) $$\overline{P}_i = \alpha + \beta \overline{C}_i + \overline{u}_i$$

51. If the true model is described by equation (5), these restrictions imply that the error term in equation (9) is the following:

(10) $$\overline{u}_i = \delta_i + \theta_i \overline{a}_i + \overline{\varepsilon}_i,$$

where $\overline{a}_i = \sum_{j=1}^{A_i} \frac{q_{ij}}{q_i} j = \frac{q_{i1}}{q_i} + \frac{q_{i2}}{q_i} 2 + \ldots + \frac{q_{iA_i}}{q_i} A_i$, A_i is the total number of periods that product i was on the market, q_{ij} is the quantity of product i sold in period j of its life-cycle, and q_i is the total quantity of product i sold over its life-cycle.

52. Accordingly, the regression in (9) yields unbiased estimates of pass-on if the following holds:

(11) $$E[\overline{u}_i \mid \overline{C}_i] = E[\delta_i \mid \overline{C}_i] + E[\theta_i \overline{a}_i \mid \overline{C}_i] = 0.$$

53. The key implication of equation (11) is that Professor Bernheim's and Professor Marx's pass-on estimates can be expected to be biased upward if a manufacturer's higher quality products tend to cost more to make and are priced at higher margins.

b. Professor Bernheim's Equation 6

54. Professor Bernheim's equation 6 regresses a measure of the average price of a product on a measure of the average cost of manufacturing the product and "product category" fixed effects:

(12) $$\overline{P}_i = \alpha + \beta \overline{C}_i + \rho_d + \overline{u}_i,$$

where $\overline{P}_i$ is the weighted average price and $\overline{C}_i$ is the weighted average cost of product *i* calculated over the lifespan of product *i* and ρ_d are "product category" fixed effects.[41]

55. This model can be derived from the model of pass-on in equation (5) by setting the product life-cycle effects to be zero and setting the product fixed effects to be common within a "product category" *d,* where *d = 1,2, … D,* and within a category *d* there are n_d products:

[R2] $\theta_i = 0$, for all *i*.

[R3]
$$\begin{aligned}
&\delta_1 = \delta_2 = \ldots = \delta_{n_1} = \rho_1 \\
&\delta_{n_1+1} = \delta_{n_1+2} = \ldots = \delta_{n_2} = \rho_2 \\
&\ldots \\
&\delta_{n_{D-1}+1} = \delta_{n_{D-1}+2} = \ldots = \delta_I = \rho_D
\end{aligned}$$

56. For example, if product category "2" contains three distinct products, A, B and C, this restriction sets the product fixed effects for A, B, and C to be equal: $\delta_A = \delta_B = \delta_C = \rho_2$.

57. Averaging the data across periods for each product yields:

(13) $$\overline{P}_i = \alpha + \beta\overline{C}_i + \rho_d + \overline{u}_i$$

58. If the true model is as described in equation (5), these restrictions imply that the error term in equation (13) is the following:

(14) $$\overline{u}_i = (\delta_i - \rho_d) + \theta_i\overline{a}_i + \overline{\varepsilon}_i.$$

where $\overline{a}_i = \sum_{j=1}^{A_i} \frac{q_{ij}}{q_i} j = \frac{q_{i1}}{q_i} + \frac{q_{i2}}{q_i} 2 + \ldots + \frac{q_{iA_i}}{q_i} A_i$ and A_i is the total number of periods that product *i* was on the market.

41 Inclusion of the parameter ρ_d is equivalent to including a separate intercept for every specific product category.

59. The pass-on regression in (13) yields unbiased estimates of pass-on if the following holds:

(15) $$E\left[\overline{u}_i \middle| \overline{C}_i, \rho_d\right] = E\left[\delta_i - \rho_d \middle| \overline{C}_i, \rho_d\right] + E\left[\theta_i \overline{a}_i \middle| \overline{C}_i, \rho_d\right] = 0$$

60. The key implication of equation (15) is that Professor Bernheim's pass-on estimate can be expected to be biased upward if, within "product categories," a manufacturer's higher quality products tend to cost more to make and are priced at higher margins.

c. Professor Bernheim's Equation 8

61. Professor Bernheim's equation 8 regresses a measure of the average price of a product on a measure of the average cost of manufacturing the product, "product category" fixed effects, and "time period" fixed effects.

62. This model can be derived from the model of pass-on in equation (5) by setting the product life-cycle effects to be zero, by setting the product fixed effects to be common within a "product category" *d,* where $d = \{1,2, \ldots D\}$ and within a category *d* there are n_d products, and by including time period fixed effects:

[R2] $\theta_i = 0$, for all *i*.

[R3]
$$\begin{aligned}
&\delta_1 = \delta_2 = \ldots = \delta_{n_1} = \rho_1 \\
&\delta_{n_1+1} = \delta_{n_1+2} = \ldots = \delta_{n_2} = \rho_2 \\
&\ldots \\
&\delta_{n_{D-1}+1} = \delta_{n_{D-1}+2} = \ldots = \delta_I = \rho_D
\end{aligned}$$

63. These restrictions lead to the following model:

(16) $$P_{iat} = \alpha + \beta C_{iat} + \tau_t + \rho_d + u_{iat}.$$

64. Taking a quantity-weighted average of the data across periods for each product yields:

(17) $$\overline{P}_i = \alpha + \beta \overline{C}_i + \sum_{t=1}^{T} \tau_t \frac{q_{it}}{q_i} + \rho_d + \overline{u}_i,$$

where q_{it} is the total quantity of product *i* sold in period *t* and q_i is the total quantity of product *i* sold across all periods.

65. If the true model is as described in equation (5), these restrictions imply that the error term in equation (17) is the following:

(18) $$\bar{u}_i = (\delta_i - \rho_d) + \left(\theta_i \bar{a}_i - \sum_{t=1}^{T} \tau_t \frac{q_{it}}{q_i} \right) + \bar{\varepsilon}_i .$$

66. The pass-on regression in (17) yields unbiased estimates of pass-on if the following holds:

(19)

$$E[\bar{u}_i \,|\bar{C}_i, \frac{q_{i1}}{q_i}, \dots, \frac{q_{iT}}{q_i}, \rho_d]$$
$$= E[\delta_i - \rho_d \,|\bar{C}_i, \frac{q_{i1}}{q_i}, \dots, \frac{q_{iT}}{q_i}, \rho_d]$$
$$+ E\left[\theta_i \bar{a}_i - \sum_{t=1}^{T} \tau_t \frac{q_{it}}{q_i} \,|\bar{C}_i, \frac{q_{i1}}{q_i}, \dots, \frac{q_{iT}}{q_i}, \rho_d\right] = 0.$$

67. The key implication of equation (19) is that Professor Bernheim's pass-on estimate can be expected to be biased upward if, within "product categories," a manufacturer's higher quality products tend to cost more to make and are priced at higher margins.

d. Professor Bernheim's Equation 10 and Professor Marx's Equation 3

68. The specification shown in row [D] of Table 1 regresses the average price of a product in a given period on the average cost of the product in the same period and a product fixed effect.

69. This model can be derived from the model of pass-on in equation (5) by setting the product life-cycle effects to zero:

[R2] $\theta_i = 0$, for all *i*.

70. This restriction leads to the following model:

(20) $$P_{iat} = \alpha + \beta C_{iat} + \delta_i + u_{iat}.$$

71. If the true model is as described in equation (5), this restriction implies that the error term in equation (20) is the following:

(21) $$u_{iat} = \theta_i a + \varepsilon_{iat}.$$

72. The pass-on regression in (20) yields an unbiased estimate of pass-on if the following holds:

(22) $$E\left[u_{iat} | C_{iat}, \delta_i\right] = E\left[\theta_i a | C_{iat}, \delta_i\right] = 0.$$

73. The key implication of equation (22) is that the pass-on estimate in equation (20) can be expected to be biased upward if product demand and product cost are positively correlated over the product life-cycle (e.g., if product demand weakens and cost falls over the product life-cycle).

e. Dr. Macartney's Upstream Pass-On Analysis

74. Dr. Macartney's upstream pass-on specification regresses the price that Kodak paid for a digital camera on the cost of an LCD panel, denoted c_{it}, "wage and shipping costs faced by OEMs"[42] and digital camera model fixed effects:

(23) $$ln(P_{iat}) = \alpha + \beta_1 ln(c_{it}) + \beta_2 ln(w_t) + \beta_3 ln(s_t) + \delta_i + u_{iat}.$$

75. This model can be derived from the log-linear version of equation (5) by setting the product life-cycle effect to be zero, replacing product cost with panel cost, and including two proxies for wage and shipping costs faced by OEMs:

[R2] $\theta_i = 0$, for all i.

42 Macartney Report, p. 72.

76. If the true model is the log-linear version of equation (5), this restriction implies that the error term in equation (23) is the following:

(24) $$u_{iat} = \theta_i a - \beta_2 \, ln(w_t) - \beta_3 \, ln(s_t) + \beta_1 (ln(C_{iat}) - ln(c_{it})) + \varepsilon_{iat}.$$

77. The pass-on regression in (23) yields unbiased estimates of pass-on if the following holds:

(25) $$\begin{aligned} &E\left[u_{iat} | ln(c_{it}), ln(w_t), ln(s_t), \delta_i\right] \\ &= E\left[\theta_i a - \beta_2 \, ln(w_t) - \beta_3 \, ln(s_t) + \beta_1 (ln(C_{iat}) - ln(c_{it})) | ln(c_{it}), ln(w_t), ln(s_t), \delta_i\right] = 0. \end{aligned}$$

78. The key implication of equation (25) is that Dr. Macartney's pass-on estimate can be expected to be biased upward if product demand and panel cost are positively correlated over the product life-cycle.

f. Dr. Macartney's Downstream Pass-On Analysis

79. Dr. Macartney's downstream pass-on specification regresses the price that Kodak charged for a digital camera on the price that Kodak paid for a digital camera, in addition to camera model fixed effects and a product life-cycle effect:

(26) $$ln(P_{iat}) = \alpha + \beta \, ln(C_{iat}) + \delta_i + \varphi a + u_{iat}.$$

80. This model can be derived from the log-linear version of equation (5) by restricting the product life-cycle effect to be common across all products:

[R4] $\theta_i = \varphi$, for all *i*.

81. If the true model is the log-linear version of equation (5), this restriction implies that the error term in equation (26) is the following:

(27) $$u_{iat} = (\theta_i - \varphi) a + \varepsilon_{iat}.$$

82. The pass-on regression in (26) yields unbiased estimates of pass-on if the following holds:

(28) $$E\left[u_{iat} | ln(C_{iat}), \delta_i, a\right] = E\left[(\theta_i - \varphi) | ln(C_{iat}), \delta_i, a\right] = 0.$$

g. Dr. Rao's Pass-on Analysis

83. Dr. Rao regresses the change in the price of a Dell monitor on the lagged change in the cost of the LCD panel used in the Dell monitor (Δc_{it-1}) and a proxy for the change in demand for Dell monitors (Δx_t):

(29) $$\Delta P_{iat} = \beta_1 \Delta c_{it-1} + \beta_2 \Delta x_t + \Delta u_{iat}.$$

84. This model can be derived from the model of pass-on in equation (6) by setting the product life-cycle effects to be zero:

[R2] $\theta_i = 0$, for all i.

85. If the true model is as described in equation (6), then this restriction implies that the error term in equation (29) is the following:

(30) $$\Delta u_{iat} = \theta_i - \beta_2 \Delta x_t + \beta_1 (\Delta C_{iat} - \Delta c_{it-1}) + \Delta \varepsilon_{iat}.$$

86. The pass-on regression in (29) yields unbiased estimates of pass-on if the following holds:

(31) $$E\left[\Delta u_{iat} | \Delta c_{it-1}, \Delta x_t\right] = E\left[\theta_i - \beta_2 \Delta x_t + \beta_1 (\Delta C_{iat} - \Delta c_{it-1}) | \Delta c_{it-1}, \Delta x_t\right] = 0.$$

87. The key implication of equation (31) is that Dr. Rao's pass-on estimate can be expected to be biased upward if product demand and product cost are positively correlated over the product life-cycle, and Dr. Rao's demand shifters do not adequately control for changes in product demand.

C. The Implications of Measurement Error for the Estimation of Pass-On Depend on the Suspected Form of the Measurement Error

88. In any econometric estimation of pass-on, there is always the possibility that the available data on costs will be measured with error. That is, the observed costs, C_{iat}, may be imperfect measures of "true" costs, C^*_{iat}:

(32) $$C_{iat} = C^*_{iat} + e_{iat}.$$

89. The implications of measurement error for the estimation of pass-on depend on the form of the measurement error. Measurement error can be uncorrelated with the unobserved true cost. This is often called "classical measurement error" or "classical errors-in-variables."[43] Measurement error can also be correlated with the unobserved true cost, which I will refer to as "non-classical measurement error." As I discuss below, the implications of classical and non-classical measurement error for the estimation of pass-on can be very different.

i. Classical Measurement Error

90. Classical measurement error is purely stochastic – meaning that the measure of cost observed is not systematically higher or lower than the true cost. A well-known result in econometrics is that classical measurement error will cause the estimated coefficient to be biased toward zero, and this so-called "attenuation bias" will depend on the variance of the true variable relative to the variance of the measurement error.[44] If the variance of the measurement error is relatively small, the bias toward zero will be relatively small.

91. The degree to which an econometric estimate is biased downward by classical measurement error is an empirical question. When classical measurement error is a concern though, several approaches can be taken to minimize its potential effect. One such approach is to "instrument" for cost using a variable that is correlated with cost but uncorrelated with the classical measurement error.[45] Another approach that is sometimes used in practice is to average the variable assumed to be randomly measured with error over multiple observations.[46] In the context of a pass-on regression, this approach would entail calculating the average cost per product at the month or quarter level, reducing the

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[43] Jeffrey M. Wooldridge, *Introductory Econometrics*, 2000, p. 295.

[44] Jeffrey M. Wooldridge, *Introductory Econometrics*, 2000, p. 296.

[45] Jeffrey M. Wooldridge, *Introductory Econometrics*, 2000, p. 461.

[46] See, for example, Solon, Gary, "Intergenerational Income Mobility in the United States," *The American Economic Review*, Vol. 82, No. 3, June 1992, pp. 393 – 408, p. 400.

noise to signal ratio and therefore the attenuation bias associated with potential classical measurement error.[47]

ii. Non-Classical Measurement Error

92. Non-classical measurement error is correlated with the level of the true variable. For example, measurement error could be correlated with the level of the true variable if price and cost data are imperfectly synchronized or if all relevant costs are not measured. The econometric implications of non-classical measurement error can be very different from the implications of classical measurement error. Specifically, non-classical measurement error can cause bias that is positive or negative.

93. Consider the possibility that price and cost data are imperfectly synchronized. That is, the price of product *i* observed at age *a* in period *t*, P_{iat}, is matched in the available data to a cost C_{iat}, even though the cost that was actually relevant to the determination of P_{iat} was a cost in period t′ when the product was of age a′, i.e., $C_{ia't'}$. The measurement error here is $C_{iat} - C_{ia't'}$.

94. This form of measurement error is non-classical if cost declines at different rates over the product life-cycle. For example, if cost declines more rapidly early in the product life-cycle, the measurement error $C_{iat} - C_{ia't'}$ will be larger (in absolute value) earlier in the product life-cycle when the level of cost is higher. This would mean that the true level of cost $C_{ia't'}$ will be correlated with the measurement error $C_{iat} - C_{ia't'}$.

95. This form of measurement error will have implications for the estimation of pass-on. The econometrician would like to estimate the model given by equation (33):

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[47] See, for example, Peter John Davis and Eliana Garcés, *Quantitative Techniques for Competition and Antitrust Analysis*, Princeton University Press, 2010, p. 496. ("Adding together two independent random measurement error terms will not reduce variance – aggregation will add up the noise. On the other hand, averaging will reduce variance.")

(33) $$P_{iat} = \alpha + \beta C_{ia't'} + \delta_i + \theta_i a + \varepsilon_{iat} ,$$

but instead will estimate the model given by equation (34):

(34) $$P_{iat} = \alpha + \beta C_{iat} + \delta_i + \theta_i a + [\beta(C_{ia't'} - C_{iat}) + \varepsilon_{iat}] ,$$

where the brackets denote the error term.

96. The error term in equation (34) is positively correlated with both P_{iat} and C_{iat} if cost declines more rapidly early in the product life-cycle when the level of cost is also relatively high. This implies that the estimate of β in this example will be biased upward.

iii. Summary

97. In summary, measurement error can be relevant to the estimation of pass-on, but the specific implications of measurement error are context specific. Classical measurement error may cause a downward bias in the estimated rate of pass-on, but steps can be taken to reduce its potential effect. Non-classical measurement error can cause an upward or downward bias in the estimated rate of pass-on. In the example provided above, price and cost data that are imperfectly synchronized can cause the estimated rate of pass-on to be biased upward, though other forms of non-classical measurement error could conceivably have the opposite effect. Ultimately, the effect of measurement error on the estimation of pass-on is an empirical question.

IV. CONCLUSIONS

98. The rate of pass-on depends crucially on the shape of the demand curve that a firm faces. Pass-on rates can be above, below, or equal to 100 percent. At the end of the day, pass-on is an empirical issue.

99. Given that pass-on rates must be estimated, it is important to do so correctly. Finished LCD products are not widgets. They are not all the same quality, they do not all have identical price/cost margins, and they have life-cycles during which demand (and price)

falls. Higher cost products can have higher margins. These characteristics have important implications for the econometric estimation of pass-on because they can be correlated in specific ways with product cost. Ignoring predictable variation in costs, margins and product life-cycle effects presents an omitted variables problem. By omitting key variables, econometric estimates of pass-on can be biased. Including what would otherwise be an omitted variable is an appropriate way to obtain estimates of pass-on that are unbiased. With one exception, all of the estimating equations put forth by Plaintiffs' experts fail to control for both product quality and product life-cycle effects.

100. Finally, measurement error of costs is another potential source of econometric bias. Unlike the case of the omitted variable bias – where simple economics can help sign the likely bias – measurement error may lead to upward or downward biased estimates of pass-on. The sign of the bias depends on whether the measurement error is classical or non-classical and, in the case of the latter, the particular statistical properties of the measurement error.

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